

CERTIFICATION OF TRANSLATION

I, Eun-Sook Lee, an employee of Y.P.LEE, MOCK & PARTNERS of Koryo Bldg., 1575-1 Seocho-dong, Seocho-gu, Seoul, Republic of Korea, hereby declare under penalty of perjury that I understand the Korean language and the English language; that I am fully capable of translating from Korean to English and vice versa; and that, to the best of my knowledge and belief, the statement in the English language in the attached translation of Korean Patent Application No. 10-2003-0014001 consisting of 34 pages have the same meanings as the statements in the Korean language in the original document, a copy of which I have examined.

Signed this 8th day of March 2007

Lee E.S.

ABSTRACT

[Abstract of the Disclosure]

5 Provided is a flat panel display which can adjust a white balance to a proper level
without changing the sizes of driving TFT active layers, even when an identical driving
voltage is applied. The flat panel display also can obtain an appropriate luminance and
prevents a reduction of its life span by supplying an optimal amount of current to each
sub-pixel. The flat panel display includes a plurality of pixels and driving thin film
transistors. Each of the pixels includes a plurality of sub-pixels, each sub-pixel having
10 a self-luminescent element. Each of the driving thin film transistors is included in each
of the sub-pixels, has a semiconductor active layer having a channel region at least, is
connected to each of the self-luminescent elements to supply current to each of the
self-luminescent elements. The channel regions of the semiconductor active layers
are arranged in different directions in at least two sub-pixels.

15 [Representative Drawing]

FIG. 1

SPECIFICATION

[Title of the Invention]

5 FLAT PANEL DISPLAY WITH THIN FILM TRANSISTOR (TFT)

[Brief Description of the Drawings]

 The above and/or other aspects and advantages of the invention will become
apparent from the following description of the embodiments, taken in conjunction with
10 the accompanying drawings in which:

 FIG. 1 is a plan view of a structure of a TFT active layer of an AM-type organic
EL display according to a preferred embodiment of the present invention;

 FIG. 2 is a plan view of an anisotropic crystal structure of a polycrystalline silicon
thin film that forms a TFT active layer;

15 FIG. 3 is a graph showing a relationship between a direction of an active layer
and a mobility of a channel region;

 FIG. 4 is a graph showing a relationship between a direction of an active layer
and a current ratio;

 FIG. 5 is a plan view of the polycrystalline silicon thin film of FIG. 2 in which
20 active layers are arranged in different directions according to an anisotropic crystal
structure;

 FIG. 6 is a partially magnified plan view of a unit pixel of FIG. 1;

 FIG. 7 is an equivalent circuit diagram of the unit pixel of FIG. 6;

 FIG. 8 is a cross-section taken along line I-I of FIG. 6; and

25 FIG. 9 is a cross-section taken along line II-II of FIG. 6.

[Detailed Description of the Invention]

[Object of the Invention]

[Technical Field of the Invention and Related Art prior to the Invention]

The present invention relates to an active matrix (AM)-type flat panel display including thin film transistors, and more particularly, to a flat panel display including polycrystalline silicon active layers and thin film transistors arranged in different directions in sub-pixels.

5 Thin film transistors (TFTs) are used as switching units to control the operations of pixels or as driving units to drive pixels in flat panel displays, such as, liquid crystal displays (LCDs) or organic or inorganic electro-luminescent (EL) displays.

 A thin film transistor has a semiconductor active layer, a gate insulating layer formed on the semiconductor active layer, and a gate electrode. In the semiconductor
10 active layer, a drain region and a source region are doped with impurities of a high concentration, and a channel region is formed between the drain and source regions. The gate electrode is formed on the gate insulating layer over the channel region of the semiconductor active layer. The semiconductor active layer can be either an amorphous silicon layer or a polycrystalline silicon layer.

15 Thin film transistors using amorphous silicon can be deposited at a low temperature, but have degraded electrical characteristics and low reliability, and as such, they are not suitable for large-sized display devices. Hence, polycrystalline silicon thin film transistors are widely used of late. Since a polycrystalline silicon has a high mobility of several tens through several hundreds of $\text{cm}^2/\text{V}\cdot\text{s}$, a low high-frequency
20 operating characteristic, and a low current leakage value, the polycrystalline silicon is very suitable for use in large, high-definition flat panel displays.

 As described above, thin film transistors are used as switching units or pixel driving units in flat panel displays. An AM-type organic EL display includes at least two thin film transistors (hereinafter, referred to as TFTs) for each sub-pixel.

25 An organic EL element has an organic luminescent layer between an anode and a cathode. In the organic EL element, as an anode voltage and a cathode voltage are applied to the anode and the cathode, respectively, holes introduced from the anode are transported to the luminescent layer via a hole transport layer, and electrons introduced from the cathode are transported to the luminescent layer via an electron transport layer.

In the luminescent layer, the electrons and the holes are combined to produce excitons. As the excited state of the excitons is changed to a ground state, fluorescent molecules on the luminescent layer emit light to form an image. In full-color organic EL displays, pixels emitting three colors, namely, red (R), green (G), and blue (B), are included as an organic EL element to achieve a full-color display.

However, in such organic EL displays, R, G, and B luminescent layers emitting R, G, and B light, respectively, have different luminescent efficiency (cd/A) for colors. Since the luminescence of the luminescent layers is approximately proportional to a current value applied to each sub-pixel, for the same current applied to sub-pixels, some colors have low luminescence and some colors have high luminescence. Accordingly, achieving a proper color balance or white balance is difficult. For example, if the luminescent efficiency of the G luminescent layer is 3 to 6 times higher than those of the R and B luminescent layers, a current 3 to 6 times greater than a current for the G luminescent layer must be applied to the R and B luminescent layers in order to adjust the white balance to a proper level.

A conventional method of adjusting the white balance to a proper level as described above is disclosed in Japanese Patent Publication No. hei 5-107561, wherein different voltages supplied through a driving line, that is, different Vdd values, are applied to different pixels.

Japanese Patent Publication No. 2001-109399 discloses a method of adjusting a white balance by controlling the size of a driving TFT. To be more specific, when the width and length of a channel region in the driving TFT are W and L, respectively, different W/L ratios are applied to R, G, and B pixels to thereby control the amounts of currents flowing into R, G, and B organic EL elements.

Japanese Patent Publication No. 2001-290441 discloses a method of adjusting a white balance by forming pixels of different colors to have different sizes. In this method, a green luminescent region with the highest luminescent efficiency is formed to have the smallest luminescent area compared to green and blue luminescent regions,

thus achieving a proper white balance and a display device with a long life span. The difference in the luminescent area can be obtained by varying the anode area.

A method of adjusting luminescence by controlling the amount of current by applying different voltage ranges to R, G, and B color pixels via a data line is also known as a conventional method of adjusting a white balance.

However, all of these methods do not consider the crystal structure of a polycrystalline silicon TFT of a flat panel display. In other words, if the direction of arrangement of TFT active layers and the crystal direction of polycrystalline silicon are considered, the mobility may vary according to these directions. In this case, the white balance cannot be adjusted using the above-described methods.

If the amount of current flowing into an organic EL element in each sub-pixel exceeds a limit value, luminescence per unit area is greatly increased by the amount of current greater than the limit value. Accordingly, the life span of the organic EL elements rapidly decreases. Thus, to increase the life span of organic EL elements, an optimal amount of current has to be supplied to each sub-pixel.

[Technical Goal of the Invention]

The present invention provides a flat panel display which can adjust a white balance to a proper level without changing the sizes of driving TFT active layers, even when an identical driving voltage is applied.

The present invention also provides a flat panel display which obtains an appropriate luminance and prevents a reduction of its life span by supplying an optimal amount of current to each sub-pixel.

[Structure and Operation of the Invention]

According to an aspect of the present invention, there is provided a flat panel display including a plurality of pixels and driving thin film transistors. Each of the pixels includes a plurality of sub-pixels, each of which has a self-luminescent element. Each of the driving thin film transistors is included in each of the sub-pixels, has a

semiconductor active layer having a channel region at least, is connected to each of the self-luminescent elements to supply current to each of the self-luminescent elements. The channel regions of the semiconductor active layers are arranged in different directions in at least two sub-pixels.

5 The sub-pixels can have different colors.

 The channel regions in the sub-pixels of different colors can be installed in different directions.

 The different directions of the channel regions can be determined by values of current flowing in the self-luminescent elements of the sub-pixels of different colors
10 when an identical driving voltage is applied to the sub-pixels of different colors.

 The different directions of the channel regions can be determined by different mobility values of the channel regions of the driving thin film transistors of the sub-pixels of different colors.

 The semiconductor active layers can be formed of polycrystalline silicon.

15 The polycrystalline silicon may have anisotropic grains.

 The different directions of the channel regions can be determined by directions of grain boundaries of the polycrystalline silicon of the channel regions.

 The different directions of the channel regions can be determined so that angles made by the current-flowing direction at the channel regions of the sub-pixels of
20 different colors and the grain boundaries of the polycrystalline silicon of the channel regions are proportional to the values of current flowing in the sub-pixels of different colors when an identical driving voltage is applied to the sub-pixels of different colors.

 The different directions of the channel regions can be determined so that the angles made by the current-flowing direction at the channel regions of the sub-pixels of
25 different colors and the grain boundaries of the polycrystalline silicon of the channel regions are proportional to the mobility values of the channel regions.

 The polycrystalline silicon can be formed using a solidification method using laser.

 According to another aspect of the present invention, there is provided a flat

panel display including a plurality of pixels and driving thin film transistors. Each of the pixels includes sub-pixels of red, green, and blue colors, each sub-pixel having a self-luminescent element. Each of the driving thin film transistors is included in each of the sub-pixels, has a semiconductor active layer having a channel region at least, is
5 connected to each of the self-luminescent elements to supply current to each of the self-luminescent elements. The channel regions of the semiconductor active layers in the sub-pixels of different colors are arranged in different directions.

The different directions of the channel regions can be determined by values of current flowing in the self-luminescent elements of the sub-pixels of different colors
10 when an identical driving voltage is applied to the sub-pixels of different colors.

The different directions of the channel regions can be determined so that a current of a smallest value flows in the self-luminescent elements of the green sub-pixels.

The different directions of the channel regions can be determined so that the
15 value of current decreases in the sequence of the self-luminescent elements of red, blue, and then green sub-pixels.

The different directions of the channel regions can be determined by mobility values of the channel regions of the driving thin film transistors of the sub-pixels of different colors.

20 The different directions of the channel regions can be determined so that the channel region of the semiconductor active layer of the self-luminescent element of a green sub-pixel has the smallest mobility value.

The different directions of the channel regions can be determined so that the mobility values of the channel regions of the driving thin film transistors decrease in the
25 sequence of red, blue, and then green sub-pixels.

The semiconductor active layers can be formed of polycrystalline silicon.

The polycrystalline silicon may have anisotropic grains.

The different directions of the channel regions can be determined by the directions of grain boundaries of the polycrystalline silicon of the channel regions.

The different directions of the channel regions can be determined so that an angle made by the current-flowing direction at the channel region of a green sub-pixel and a grain boundary of the polycrystalline silicon of the channel region of the green sub-pixel is greater than the angles made by the current-flowing direction at the channel regions of the red and blue sub-pixels with grain boundaries of the polycrystalline silicon of the channel regions of the red and blue sub-pixels.

The different directions of the channel regions can be determined so that an angle made by the current-flowing direction at the channel region of a red sub-pixel and a grain boundary of the polycrystalline silicon of the channel region of the red sub-pixel is smaller than the angles made by the current-flowing direction at the channel regions of the green and blue sub-pixels with grain boundaries of the polycrystalline silicon of the channel regions of the green and blue sub-pixels.

The different directions of the channel regions can be determined so that an angle made by the current-flowing direction at the channel region of a sub-pixel and a grain boundary of the polycrystalline silicon of the channel region of the driving thin film transistor of the sub-pixel decreases in sequence of green, blue, and then red sub-pixels.

The polycrystalline silicon can have primary grain boundaries parallel to one another and secondary grain boundaries each approximately perpendicular to the primary grain boundaries and located between adjacent primary grain boundaries.

The different directions of the channel regions can be determined with respect to the direction of the primary grain boundaries of the polycrystalline silicon of the channel regions.

The different directions of the channel regions can be determined so that an angle made by the current-flowing direction at the channel region of a green sub-pixel and a primary grain boundary of the polycrystalline silicon of the channel region of the green sub-pixel is greater than angles made by the current-flowing direction at the channel regions of the red and blue sub-pixels with the primary grain boundaries of the polycrystalline silicon of the channel regions of the red and blue sub-pixels.

The different directions of the channel regions can be determined so that an angle made by the current-flowing direction at the channel region of a red sub-pixel and a primary grain boundary of the polycrystalline silicon of the channel region of the red sub-pixel is smaller than angles made by the current-flowing direction at the channel regions of the green and blue sub-pixels with grain boundaries of the polycrystalline silicon of the channel regions of the green and blue sub-pixels.

The different directions of the channel regions can be determined so that an angle made by the current-flowing direction at the channel region of a sub-pixel and a primary grain boundary of the polycrystalline silicon of the channel region of the sub-pixel decreases in sequence of green, blue, and then red sub-pixels.

The current-flowing direction at the channel region of each of the green sub-pixels can be parallel to a primary grain boundary of the polycrystalline silicon of the channel region.

The current-flowing direction at the channel region of each of the red sub-pixels can be perpendicular to a primary grain boundary of the polycrystalline silicon of the channel region.

The polycrystalline silicon can be formed using a solidification method using laser.

FIG. 1 is a plan view of a structure of a TFT active layer of an AM-type organic EL display according to a preferred embodiment of the present invention. Referring to FIG. 1, the organic EL display includes a plurality of pixels, each of which is formed by repetitively arranging of a group of R, G, and B sub-pixels in a vertical direction. However, the present invention is not limited to the above sub-pixel arrangement. For example, sub-pixels of different colors can be arranged in various patterns, such as, a mosaic pattern or a lattice pattern to form a pixel.

In the organic EL display of FIG. 1, a plurality of gate lines 51 are arranged horizontally, and a plurality of data lines 52 are arranged vertically. Driving lines 53 for supplying power are also arranged vertically. One sub-pixel is defined by one gate line 51, one data line 52, and one driving line 53.

Each of the sub-pixels includes at least two TFTs, that is, first and second TFTs. First TFTs 10r, 10g, and 10b can be switching TFTs for controlling the operations of organic EL elements using a signal via a gate line 51, and second TFTs 20r, 20g, and 20b can be driving TFTs for driving the organic EL elements. Of course, the number of
5 TFTs and the arrangement of the TFTs can vary depending on the characteristics of a display, the type of a driving method, or the like.

The first TFTs 10r, 10g, and 10b have first semiconductor active layers 11r, 11g, and 11b, respectively, and the second TFTs 20r, 20g, and 20b have second semiconductor active layers 21r, 21g, and 21b, respectively. Each of these
10 semiconductor active layers has a channel region (not shown), which will be described later. The channel region is located nearly at the center of each of the first semiconductor active layers 11r, 11g, and 11b, and the second semiconductor active layers 21r, 21g, and 21b, and is formed under a gate electrode so as to be insulated from the gate electrode.

As can be seen from FIG. 1, the second semiconductor active layers 21r, 21g, and 21b, which constitute a driving TFT, can be arranged in different directions in different sub-pixels, more specifically, for different colors. In other words, the second semiconductor active layers 21r, which constitute a red pixel (R), the second semiconductor active layers 21g, which constitute a green pixel (G), and the second
20 semiconductor active layers 21b, which constitute a blue pixel (B), are arranged in different directions for pixels of different colors. If the R, G, and B sub-pixels are arranged in a mosaic pattern instead of strips as shown in FIG. 1, the second semiconductor active layers are arranged in different directions while keeping the mosaic pattern. If the sub-pixels have colors other than red, green, and blue, the
25 second semiconductor active layers are still arranged in different directions for different colors.

The first semiconductor active layers 11r, 11g, and 11b and the second semiconductor active layers 21r, 21g, and 21b may be thinly formed of polycrystalline silicon. As described above, the second semiconductor active layers 21r, 21g, and

21b are arranged in different directions for R, G, and B sub-pixels. To be more specific, only the channel regions at the centers of the second semiconductor active layers 21r, 21g, and 21b can have different directions. However, FIG. 1 shows the arrangement of the second semiconductor active layers in their entirety in different directions in order to avoid a complicate structure drawing. Hence, the arrangement directions of TFT active layers will now replace the directions of arrangement of channel regions of the TFT active layers, which means that only the channel regions of TFT active layers, not the TFT active layers in their entirety, can be arranged in different directions. This fact will refer equally to all embodiments to be described later.

According to the present invention, as the channel regions of second semiconductor active layers of the second TFTs, which are used as driving TFTs, have different directions for R, G, and B sub-pixels, the semiconductor active layers can have the same size, and a white balance can be obtained even when an identical driving voltage is applied to the R, G, and B sub-pixels. This principle will now be described in greater detail.

As described above, in organic EL displays, the luminescent layers of the R, G, and B pixels have different luminescent efficiency and accordingly provide different luminescence values. Hence, a white balance cannot be obtained when an identical current is applied to all three luminescent layers. Table 1 shows the efficiency of R, G, and B organic luminescent layers, which are widely used in current organic EL displays, and current values to be applied to R, G, and B sub-pixels so as to obtain a white balance.

[Table 1]

	Red	Green	Blue
Efficiency (Cd/A)	6.72	23.37	4.21
Pixel current (μ A)	0.276	0.079	0.230
Pixel current ratio	3.5	1	2.9

As can be seen from Table 1, to achieve a white balance, the smallest value of current is applied to green sub-pixels, followed by a current value for blue sub-pixels. The greatest value of current is applied to red sub-pixels.

The difference in current value can be obtained by differentiating the directions in which the semiconductor active layers 21r, 21g, and 21b of the second TFTs 20r, 20g, and 20b of FIG. 1, which are driving TFTs for supplying current to luminescent elements, are arranged. In other words, due to the arrangement of the active layers 21r, 21g, and 21b of the second TFTs 20r, 20g, and 20b in different directions, different values of current have to be applied to luminescent elements (for example, organic EL elements) of R, G, and B sub-pixels having the second TFTs 20r, 20g, and 20b.

In other words, the directions of the active layers 21r, 21g, and 21b of the second TFTs 20r, 20g, and 20b are determined by the values of currents flowing in the organic EL elements of the sub-pixels at an identical driving voltage. Hence, to obtain a white balance, the active layers 21g of the second TFTs 20g in green sub-pixels must be arranged in a direction that enables a current of the lowest value to be applied to the organic EL elements of the green sub-pixels with the greatest luminance. Preferably, the directions of the active layers 21r, 21g, and 21b of the second TFTs 20r, 20g, and 20b are controlled so that the current values applied to the organic EL elements of the sub-pixels decrease in the order of R, B, and then G sub-pixels. In other words, the directions of the second active layers 21r are determined so that a current of the greatest value can be applied to the organic EL elements of red sub-pixels, the directions of the second active layers 21b are determined so that a current of the second greatest value can be applied to the organic EL elements of the blue sub-pixels, and the directions of the second active layers 21g are determined so that a current of the smallest value can be applied to the organic EL elements of green sub-pixels. Accordingly, the luminance of each of the R, G, and B sub-pixels is compensated for so that the white balance can be adjusted to a proper level.

The directions of the active layers 21r, 21g, and 21b of the second TFTs 20r, 20g, and 20b can also be determined according to the mobility of the channel regions of the

active layers. This is because a large current can flow in the channel region when a channel region has a high mobility, and a small current can flow in the channel region when a channel region has a low mobility.

Hence, to obtain a white balance, the active layers 21g of the second TFTs 20g in green sub-pixels must be arranged in a direction that enables the green sub-pixels with the greatest luminance to have the lowest mobility. Preferably, the directions of the active layers 21r, 21g, and 21b of the second TFTs 20r, 20g, and 20b are controlled so that the mobility of a channel region of an active layer of a second TFT decreases in the order of R, B, and then G sub-pixels. In other words, the directions of the second active layers 21r are determined so that their channel regions can have the greatest mobility, the directions of the second active layers 21b are determined so that their channel regions can have the second greatest mobility, and the directions of the second active layers 21g are determined so that their channel regions can have the smallest mobility. Accordingly, currents of different values flow in the organic EL elements of the R, G, and B sub-pixels as described above, and the luminance of each of the R, G, and B sub-pixels is compensated for. Thus, the white balance can be adjusted to a proper level.

The difference in current value and the difference in mobility can vary according to the crystal structure of polycrystalline silicon of which active layers are formed. In other words, different current values and different mobility for R, G, and B sub-pixels can be obtained by differentiating the directions of the active layers in R, G, and B sub-pixels according to the crystal structure of polycrystalline silicon. This will now be described in greater detail.

FIG. 2 is a plan view of the anisotropic crystal structure of a polycrystalline silicon thin film that forms a TFT active layer. A polycrystalline silicon thin film with an anisotropic crystal structure as shown in FIG. 2 is obtained by solidifying an amorphous silicon thin film using a well-known sequential lateral solidification method (hereinafter, referred to as an SLS method). Such an anisotropic crystal structure is not limited to the crystal structure formed by the SLS method but can be formed in any solidification

method that enables a polycrystalline silicon thin film to have an anisotropic crystal structure. Preferably, a solidification method using laser can be used.

The SLS method is based on the fact that silicon grains grow on the boundary between a liquid portion of silicon and a solid portion of silicon in a direction
5 perpendicular to the boundary surface. In the SLS method, amorphous silicon is partially melted by projecting a laser beam onto a mask that covers the amorphous silicon, and a melted silicon portion grows from the boundary between the melted silicon portion and a not-melted silicon portion and is then solidified.

As can be seen from FIG. 2, a crystal structure formed by the SLS method
10 comprises a plurality of primary grain boundaries 61, which are isolated from one another at predetermined intervals, and a plurality of secondary grain boundaries 62, which exist between adjacent primary grain boundaries 61 and extend in a direction approximately perpendicular to the primary grain boundaries 61. The primary grain boundaries 61 are formed by the secondary grain boundaries 62 that meet each other.
15 The secondary grain boundaries 62 are arranged more densely than the primary grain boundaries 61. Each of the secondary grain boundaries 62 melts by light passed through a mask and grows. Accordingly, a silicon thin film 60 has the secondary grain boundaries 62 formed longitudinally between the primary grain boundaries 61.

Because the silicon thin film 60 having the primary and secondary grain
20 boundaries 61 and 62 has such an anisotropic crystal structure, a TFT can have an anisotropic structure depending on the direction of a channel region of an active layer to be formed like the silicon thin film 60. In other words, the mobility and current value of a channel region in the silicon thin film 60 having an anisotropic crystal structure vary according to a direction in which the channel region is formed.

FIGS. 3 and 4 show the mobility and current ratio, respectively, of a channel
25 region of an active layer versus an angle formed by the primary grain boundaries 61 and the direction of current flowing in the channel region of the active layer. In FIGS. 3 and 4, a rotation angle denotes an angle formed by the current flowing direction at a

channel region of an active layer and the primary grain boundaries 61 approximately perpendicular to the secondary grain boundaries 62.

In FIG. 3, P denotes the mobility of a TFT measured from source and drain regions to which P-type impurities are added, and N denotes the mobility of a TFT measured from source and drain regions to which N-type impurities are added. As can be seen from FIG. 3, the mobility of the channel region of a TFT increases as the angle formed by the current-flowing direction at the channel region and each of the primary grain boundaries 61 increases. Accordingly, the mobility increases as the rotation angle increases from 0 degrees to 90 degrees.

This phenomenon can be interpreted as an effect of the resisting properties on the motion of carriers. If the current-flowing direction at the channel region of an active layer makes 0 degrees with the primary grain boundaries 61, that is, if the current-flowing direction at the channel region is approximately perpendicular to the secondary grain boundaries 62, carriers move in a direction perpendicular to the secondary grain boundaries 62, and accordingly, a resistance against the motion of carrier is large. Hence, the channel region has a low mobility. If the current-flowing direction at the channel region of an active layer makes 90 degrees with the primary grain boundaries 61, that is, if the current-flowing direction at the channel region is approximately parallel to the secondary grain boundaries 62, carriers move in a direction parallel to the secondary grain boundaries 62, and accordingly, the resistance against the motion of carrier is small. Hence, the channel region has a high mobility.

As shown in FIG. 4, the difference in mobility between the aforementioned two cases can be represented as a difference in current ratio. It can be seen from FIG. 4 that as the angle formed by the current-flowing direction at the channel region of an active layer and the primary grain boundaries 61 increases, a current ratio increases. Referring to FIG. 4, when the current-flowing direction at the channel region of an active layer makes 90 degrees with the primary grain boundaries 61, that is, when the current-flowing direction at the channel region is approximately parallel to the secondary grain boundaries 62, a current value is at least 3.5 times greater than when the

current-flowing direction at the channel region makes 0 degrees with the primary grain boundaries 61. Hence, the channel region of a driving TFT in red sub-pixels, which need the current of the greatest value, is designed such as to make 90 degrees with the primary grain boundaries 61. The channel region of a driving TFT in green sub-pixels, which need the current of the smallest value, is designed such as to make 0 degrees with the primary grain boundaries 61. By doing this, even when active layers are identical in size, and an identical driving voltage is applied to all sub-pixels, a white balance can be achieved. In this case, the channel region of a driving TFT in blue sub-pixels can be rotated to make a certain angle in the range of 0 to 90 degrees with the primary grain boundaries 61. In EL elements having the data shown in Table 1, the channel region of a driving TFT in blue sub-pixels can be designed such as to make a certain angle in the range of 70 to 75 degrees with the primary grain boundaries 61.

FIG. 5 is a plan view of the silicon thin film 60 of FIG. 2 in which a second semiconductor active layer 21r, a second semiconductor active layer 21g, and a second semiconductor active layer 21b are arranged in different directions with respect to the direction of the primary grain boundaries 61.

As shown in FIG. 5, the second semiconductor active layer 21r is disposed such that the current-flowing direction at a channel region C1 is approximately parallel to the secondary grain boundaries 62, that is, the current-flowing direction at the channel region C1 makes 90 degrees with the primary grain boundaries 61. The second semiconductor active layer 21g is disposed such that the current-flowing direction at a channel region C2 is perpendicular to the secondary grain boundaries 62, that is, the current-flowing direction at the channel region C2 makes 0 degrees with the primary grain boundaries 61. The second semiconductor active layer 21B is disposed such that the current-flowing direction at a channel region C3 is inclined with respect to the secondary grain boundaries 62, that is, the primary grain boundaries 61.

The inclination angles of the second semiconductor active layers 21r, 21g, and 21b may vary depending on the type of an organic material used. After the luminance of each pixel and a current ratio for a white balance are calculated in advance, the

inclination values of the second semiconductor active layers of red and blue sub-pixels are determined based on the inclination value of the second semiconductor active layer of a green sub-pixel.

The second semiconductor active layers 21r, 21g, and 21b of the second TFTs 20r, 20g, and 20b are arranged in different directions determined by the above method, thereby forming an organic EL display as shown in FIG. 1. In other words, although not shown in FIG. 1, the secondary grain boundaries 62 in FIG. 5 are formed vertically, and the primary grain boundaries 61 are formed horizontally. In the sub-pixels of the red pixel R, the second active layers 21r of the second TFTs 20r are all arranged in directions perpendicular to the primary grain boundaries 61, and accordingly have large mobility. Hence, the largest current can be supplied to the organic EL element of the sub-pixels of the red pixel R although an identical driving voltage is applied to all of the sub-pixels of the red, green, and blue pixels R, G, and B. In the sub-pixels of the green pixel G, the second active layers 21g of the second TFTs 20g are all arranged in directions parallel to the primary grain boundaries 61, and accordingly, have small mobility. Hence, the smallest current can be supplied to the organic EL element of the sub-pixels of the green pixel G although an identical driving voltage is applied to all of the sub-pixels of the red, green, and blue pixels R, G, and B. In the sub-pixels of the blue pixel B, the second active layers 21b of the second TFTs 20b are inclined with respect to the primary grain boundaries 61, and accordingly, they have a mobility between the mobility values for the R and G pixels and amount of current between in the R and G pixels. Hence, the R, G, and B pixels can achieve a white balance.

In the preferred embodiment of the present invention of FIG. 1, similar to the second active layers 21r of the red pixel R, the first active layers 11r, 11g, and 11b of the first TFTs 10r, 10g, and 10b, which are switching units, are arranged parallel to the secondary grain boundaries 62 to make the first TFTs 10r, 10g, and 10b have large mobility so as to improve the switching characteristics of the first TFTs 10r, 10g, and 10b. Although only the second active layers 21r, 21g, and 21b of the second TFTs 20r, 20g, and 20b are arranged in different directions for sub-pixels of different colors in FIG.

1, the first active layers 11r, 11g, and 11b of the first TFTs 10r, 10g, and 10b can also be arranged in different directions as the second active layers 21r, 21g, and 21b.

Each pixel of an organic EL display as described above has a structure shown in FIGS. 6 through 9.

FIG. 6 is a partially magnified plan view of a sub-pixel of the green pixel G among the sub-pixels of FIG. 1. The sub-pixel structure of FIG. 6 is not limited to the green pixel G but can be applied to other color pixels of the present invention. Hence, the sub-pixel of FIG. 6 does not denote a specified sub-pixel but any unspecified sub-pixel to which the present invention can be applied, and the reference numerals of FIG. 6 also indicate elements associated with an unspecified sub-pixel.

FIG. 7 is an equivalent circuit diagram of an unspecified sub-pixel of FIG. 6. Referring to FIG. 7, each of the sub-pixels of an AM-type organic EL display is made up of a first TFT 10 for use as a switching unit, a second TFT 20 for use as a driving unit, a capacitor 30, and an organic EL element 40 (hereinafter, referred to as "EL element"). The number of TFTs and the number of capacitors are not limited to the case of FIG. 7. A greater number of TFTs and capacitors than the two TFTs and one capacitor can be included according to the design conditions.

The first TFT 10 is driven in response to a scan signal applied to a gate line 51 and transmits a data signal to a data line 52. The second TFT 20 determines the amount of current flowing into the EL element 40, using the data signal received through the first TFT 10, that is, a voltage difference V_{gs} between a gate and a source. The capacitor 30 stores the data signal received through the first TFT 10, for a period of one frame.

An organic EL display having such a structure as shown in FIGS. 6, 8, and 9 is formed to achieve the circuit of FIG. 7. The structure of the organic EL display will now be described in detail.

As can be seen from FIGS. 6, 8, and 9, a buffer layer 2 is formed on a glass insulating substrate 1, and the first and second TFTs 10 and 20, the capacitor 30, and the EL element 40 are installed over the buffer layer 2.

As shown in FIG. 8, the first TFT 10 is made up of a first active layer 11, a gate electrode 13, a source electrode 14, and a drain electrode 15. The gate electrode 13 is connected to the gate line 51 of FIG. 6 and receives a TFT on/off signal via the gate line 51 and outputs the same. The source electrode 14 is located above the gate electrode 13, connected to the data line 52, and supplies a data signal to the first active layer 11. The drain electrode 15 connects the first TFT 10 to the capacitor 30 to supply power to the capacitor 30. A gate insulating layer 3 is formed between the first active layer 11 and the gate electrode 13.

The charging capacitor 30 is located between the first and second TFTs 10 and 20 and stores the amount of driving voltage necessary to drive the second TFT 20, for a period of one frame. As can be seen from FIGS. 6 and 8, the capacitor 30 can be made up of first and second electrodes 31 and 32 and an inter-insulating layer 4. The first electrode 31 is connected to the drain electrode 15 of the first TFT 10. The second electrode 32 overlaps the first electrode 31 and is electrically connected to a driving line 53, which is a power applying line. The inter-insulating layer 4 is formed between the first and second electrodes 31 and 32 and is used as a dielectric. The structure of the charging capacitor 30 is not limited to the structure shown in FIG. 8. For example, a silicon thin film for the TFT 10 and a conductive layer of the gate electrode 13 can be used as the first and second electrodes 31 and 32, respectively, and the gate insulating layer 3 can be used as a dielectric layer. Various other methods can be used.

As can be seen from FIGS. 6 and 9, the second TFT 20 is made up of a second active layer 21, a gate electrode 23, a source electrode 24, and a drain electrode 25. The gate electrode 23 is connected to the first electrode 31 of the capacitor 30 and receives a TFT on/off signal via the first electrode 31 and outputs the same. The source electrode 24 is located above the gate electrode 23, connected to the driving line 53, and supplies a reference common driving voltage to a second active layer 21. The drain electrode 25 connects the second TFT 20 to the EL element 40 to supply driving power to the EL element 40. The gate insulating layer 3 is formed between the second

active layer 21 and the gate electrode 23. Depending on the color of sub-pixels, the current-flowing direction at the channel region of the second active layer 21 is arranged parallel to, perpendicular to, or aslant to the grain boundaries of the second active layer 21.

5 The EL element 40 displays predetermined image data by emitting R, G, and B light as current flows. As can be seen from FIGS. 6 and 9, the EL element 40 is made up of an anode 41, a cathode 43, and an organic EL film 42. The anode 41 is connected to the drain electrode 25 of the second TFT 20 and receives plus power from the drain electrode 25. The cathode electrode 43 covers the entire body of a pixel and
10 supplies minus power to the pixel. The organic EL film 42 is located between the anode 42 and the cathode 43 and emits light. Reference numeral 5 denotes a SiO_2 insulative passivation film formed of SiO_2 or the like, and reference numeral 6 denotes an insulative planarization film formed of acrylic or the like.

The layer structure of an organic EL display according to the present invention is
15 not limited to the layer structure shown in FIGS. 6, 8, and 9, and other layer structures can be applied to an organic EL display according to the present invention.

The organic EL display having the above-described structure can be manufactured in the following method.

First, as shown in FIGS. 8 and 9, the buffer layer 2 is formed on the glass
20 insulating substrate 1. The buffer layer 2 can be formed of SiO_2 to a thickness of about 3000 Å by PECVD, APCVD, LPCVD, ECR, or the like.

An amorphous silicon thin film is deposited on the buffer layer 2, for example, to a thickness of about 500 Å. The amorphous silicon thin film can be solidified into a polycrystalline silicon thin film using various methods. Preferably, the polycrystalline
25 silicon thin film has an anisotropic crystal structure in which grain boundaries as shown in FIG. 2 extend lengthwise. In the preferred embodiment of the present invention, as described above, the anisotropic crystal structure is formed by SLS. However, any solidification method that can obtain an anisotropic crystal structure can be used.

After the polycrystalline silicon thin film having an anisotropic crystal structure is formed, as can be seen from FIG. 1, the second active layers 21r, 21g, and 21b of the second TFTs 20r, 20g, and 20b in sub-pixels of different colors are arranged in a pattern to have different directions with respect to the direction of grain boundaries. At this time, the first active layers 11r, 11g, and 11b are also patterned.

Thereafter, the gate insulating layer 3 is formed of SiO₂ on the patterned active layers 20r, 20g, 20b, 21r, 21g, and 21b by PECVD, APCVD, LPCVD, ECR, or the like. Then, a conductive film is formed of MoW, Al/Cu, or the like and then patterned, thereby forming gate electrodes 13 and 23. The active layers 20r, 20g, 20b, 21r, 21g, and 21b, the gate insulating layer 3, and the gate electrodes 13 and 23 can be patterned in various sequences and methods.

After the patterning of the active layers, the gate insulating layer, and the gate electrodes, their source and drain regions are doped with N- or P-type impurities.

Thereafter, as shown in FIGS. 8 and 9, the inter-insulating layer 4 and the passivation film 5 are formed, the source electrodes 14 and 24 and the drain electrodes 15 and 25 are connected to the active layers 11 and 21 via control holes, and the planarization film 6 is formed. Of course, this film structure can vary according to design conditions.

The EL element 40, which is connected to the second TFT 20, can be formed by various methods. First, the anodes 41 contacting the drain electrodes 25 of the second TFT 20 are formed of Indium Tin Oxide (ITO) in a pattern, and the organic EL film 42 is formed on the anodes 41. The organic EL film 42 can be either a monomer or polymer organic film. A monomer organic EL film can be formed by stacking a hole implementation layer, a hole transport layer, an organic EL layer, an electron transport layer, and an electron implementation layer in a simple or complex structure. Various organic materials can be used, including Copper phthalocyanine (CuPc), N, N'-Di(naphthalene-1-yl)-N, N'-diphenyl-benzidine (NPB), and tris-8-hydroxyquinoline aluminum (Alq3). These monomer organic EL films are formed by vacuum deposition.

A polymer organic EL film can be made up of a hole transport layer (HTL) and a light emitting layer (EML). Here, the hole transport layer can be formed of PEDOT, and the light emitting layer can be formed of a polymer organic material, such as, poly-phenylenevinylene (PPV)-containing material and polyfluorene-containing material, by screen printing or Inkjet printing.

After the formation of the organic EL film 42, the cathode 43 can be deposited of Al/Ca or the like on the entire surface of the organic EL film 42 or patterned. The cathode 43 is covered by a glass or metal cap.

The present invention is not limited to the above-described organic EL display but can be applied to any displays capable of using TFTs, such as, liquid crystal displays or inorganic EL displays.

[Effect of the Invention]

A flat panel display according to the present invention as described above has the following effects.

Firstly, without change in the sizes of active layers of a TFT or in driving voltage, a white balance can be obtained even with active layers of the same size.

Secondly, because an appropriate amount of current is supplied to individual sub-pixels, a proper level of luminance can be obtained, and degradation of the life span of the flat panel display can be prevented.

Thirdly, a reduction of an aperture of the flat panel display can be prevented and the reliability thereof can be improved, by controlling only the amount of current flowing in an organic EL element without increasing the area of each pixel occupied by a driving TFT.

While the present invention has been particularly shown and described with reference to exemplary embodiments thereof, it will be understood by those of ordinary skill in the art that various changes in form and details may be made therein without departing from the spirit and scope of the present invention as defined by the following claims.

What is claimed is:

1. A flat panel display comprising:

a plurality of pixels, each pixel including a plurality of sub-pixels, each sub-pixel having a self-luminescent element; and

5 driving thin film transistors, each of which is included in each of the sub-pixels, has a semiconductor active layer having a channel region at least, is connected to each of the self-luminescent elements to supply current to each of the self-luminescent elements, wherein the channel regions of the semiconductor active layers are arranged in different directions in at least two sub-pixels.

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2. The flat panel display of claim 1, wherein the sub-pixels have different colors.

3. The flat panel display of claim 2, wherein the channel regions in the
15 sub-pixels of different colors are installed in different directions.

4. The flat panel display of claim 1, wherein the different directions of the channel regions are determined by values of current flowing in the self-luminescent element of the sub-pixels of different colors when an identical driving voltage is applied
20 to the sub-pixels of different colors.

5. The flat panel display of claim 1, wherein the different directions of the channel regions are determined by different mobility values of the channel regions of the driving thin film transistors of the sub-pixels of different colors.

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6. The flat panel display of claim 1, wherein the semiconductor active layers are formed of polycrystalline silicon.

7. The flat panel display of claim 6, wherein the polycrystalline silicon has anisotropic grains.

8. The flat panel display of claim 6, wherein the different directions of the channel regions are determined by directions of grain boundaries of the polycrystalline silicon of the channel regions.

9. The flat panel display of claim 8, wherein the different directions of the channel regions are determined so that angles made by the current-flowing direction at the channel regions of the sub-pixels of different colors and the grain boundaries of the polycrystalline silicon of the channel regions are proportional to the values of current flowing in the sub-pixels of different colors when an identical driving voltage is applied to the sub-pixels of different colors.

10. The flat panel display of claim 9, wherein the different directions of the channel regions are determined so that the angles made by the current-flowing direction at the channel regions of the sub-pixels of different colors and the grain boundaries of the polycrystalline silicon of the channel regions are proportional to the mobility values of the channel regions.

11. The flat panel display of claim 6, wherein the polycrystalline silicon is formed using a solidification method using laser.

12. A flat panel display comprising:
a plurality of pixels, each pixel including sub-pixels of red, green, and blue colors, each sub-pixel having a self-luminescent element; and
driving thin film transistors, each of which is included in each of the sub-pixels, has a semiconductor active layer having a channel region at least, is connected to each of the self-luminescent elements to supply current to each of the self-luminescent

elements, wherein the channel regions of the semiconductor active layers in the sub-pixels of different colors are arranged in different directions.

13. The flat panel display of claim 12, wherein the different directions of the channel regions are determined by values of current flowing in the self-luminescent elements of the sub-pixels of different colors when an identical driving voltage is applied to the sub-pixels of different colors.

14. The flat panel display of claim 12, wherein the different directions of the channel regions are determined so that a current of a smallest value flows in the self-luminescent elements of the green sub-pixels.

15. The flat panel display of claim 13, wherein the different directions of the channel regions are determined so that the value of current decreases in the sequence of the self-luminescent elements of red, blue, and then green sub-pixels.

16. The flat panel display of claim 12, wherein the different directions of the channel regions are determined by mobility values of the channel regions of the driving thin film transistors of the sub-pixels of different colors.

17. The flat panel display of claim 16, wherein the different directions of the channel regions are determined so that the channel region of the semiconductor active layer of the driving thin film transistors of a green sub-pixel has the smallest mobility value.

18. The flat panel display of claim 16, wherein the different directions of the channel regions are determined so that the mobility values of the channel regions of the driving thin film transistors decrease in the sequence of red, blue, and then green sub-pixels.

19. The flat panel display of claim 12, wherein the semiconductor active layers are formed of polycrystalline silicon.

5 20. The flat panel display of claim 19, wherein the polycrystalline silicon has anisotropic grains.

21. The flat panel display of claim 19, wherein the different directions of the channel regions are determined by the directions of grain boundaries of the
10 polycrystalline silicon of the channel regions.

22. The flat panel display of claim 21, wherein the different directions of the channel regions are determined so that an angle made by the current-flowing direction at the channel region of a green sub-pixel and a grain boundary of the polycrystalline
15 silicon of the channel region of the green sub-pixel is greater than the angles made by the current-flowing direction at the channel regions of the red and blue sub-pixels with grain boundaries of the polycrystalline silicon of the channel regions of the red and blue sub-pixels.

20 23. The flat panel display of claim 21, wherein the different directions of the channel regions are determined so that an angle made by the current-flowing direction at the channel region of a red sub-pixel and a grain boundary of the polycrystalline silicon of the channel region of the red sub-pixel is smaller than the angles made by the
25 current-flowing direction at the channel regions of the green and blue sub-pixels with grain boundaries of the polycrystalline silicon of the channel regions of the green and blue sub-pixels.

24. The flat panel display of claim 21, wherein the different directions of the channel regions are determined so that an angle made by the channel region of a

sub-pixel and a grain boundary of the polycrystalline silicon of the channel region of the driving thin film transistor of the sub-pixel decreases in sequence of green, blue, and then red sub-pixels.

5 25. The flat panel display of claim 19, wherein the polycrystalline silicon has primary grain boundaries parallel to one another and secondary grain boundaries each approximately perpendicular to the primary grain boundaries and located between adjacent primary grain boundaries.

10 26. The flat panel display of claim 25, wherein the different directions of the channel regions are determined with respect to the direction of the primary grain boundaries of the polycrystalline silicon of the channel regions.

15 27. The flat panel display of claim 26, wherein the different directions of the channel regions are determined so that an angle made by the current-flowing direction at the channel region of a green sub-pixel and a primary grain boundary of the polycrystalline silicon of the channel region of the green sub-pixel is smaller than angles made by the current-flowing direction at the channel regions of the red and blue sub-pixels with the primary grain boundaries of the polycrystalline silicon of the channel regions of the red and blue sub-pixels.

20 28. The flat panel display of claim 26, wherein the different directions of the channel regions are determined so that an angle made by the current-flowing direction at the channel region of a red sub-pixel and a primary grain boundary of the polycrystalline silicon of the channel region of the red sub-pixel is greater than angles made by the current-flowing direction at the channel regions of the green and blue sub-pixels with grain boundaries of the polycrystalline silicon of the channel regions of the green and blue sub-pixels.

29. The flat panel display of claim 26, wherein the different directions of the channel regions are determined so that an angle made by the current-flowing direction at the channel region of a sub-pixel and a primary grain boundary of the polycrystalline silicon of the channel region of the sub-pixel decreases in sequence of green, blue, and then red sub-pixels.

30. The flat panel display of claim 26, wherein the current-flowing direction at the channel region of each of the green sub-pixels is parallel to a primary grain boundary of the polycrystalline silicon of the channel region.

31. The flat panel display of claim 26, wherein the current-flowing direction at the channel region of each of the red sub-pixels is perpendicular to a primary grain boundary of the polycrystalline silicon of the channel region.

32. The flat panel display of claim 19, wherein the polycrystalline silicon is formed using a solidification method using laser.

FIG. 1

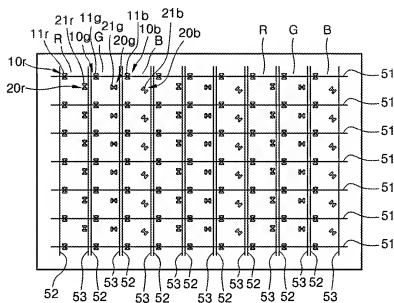


FIG. 2

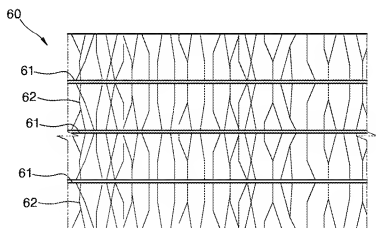


FIG. 3

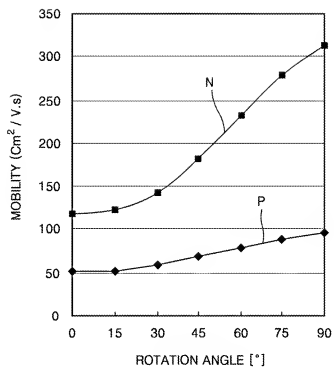


FIG. 4

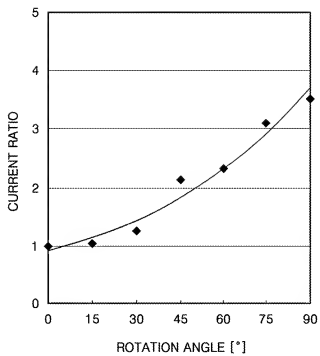


FIG. 5

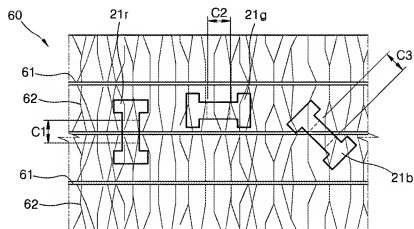


FIG. 6

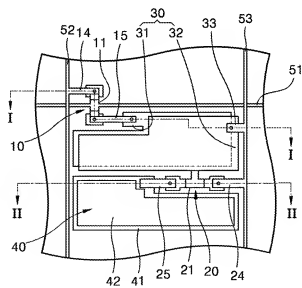


FIG. 9

